

# **Electrolytic Plasma Processing for Sequential Cleaning and Coating Deposition for Cd Plating Replacement**

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**New SERDP Project  
Initiated in August 2004**

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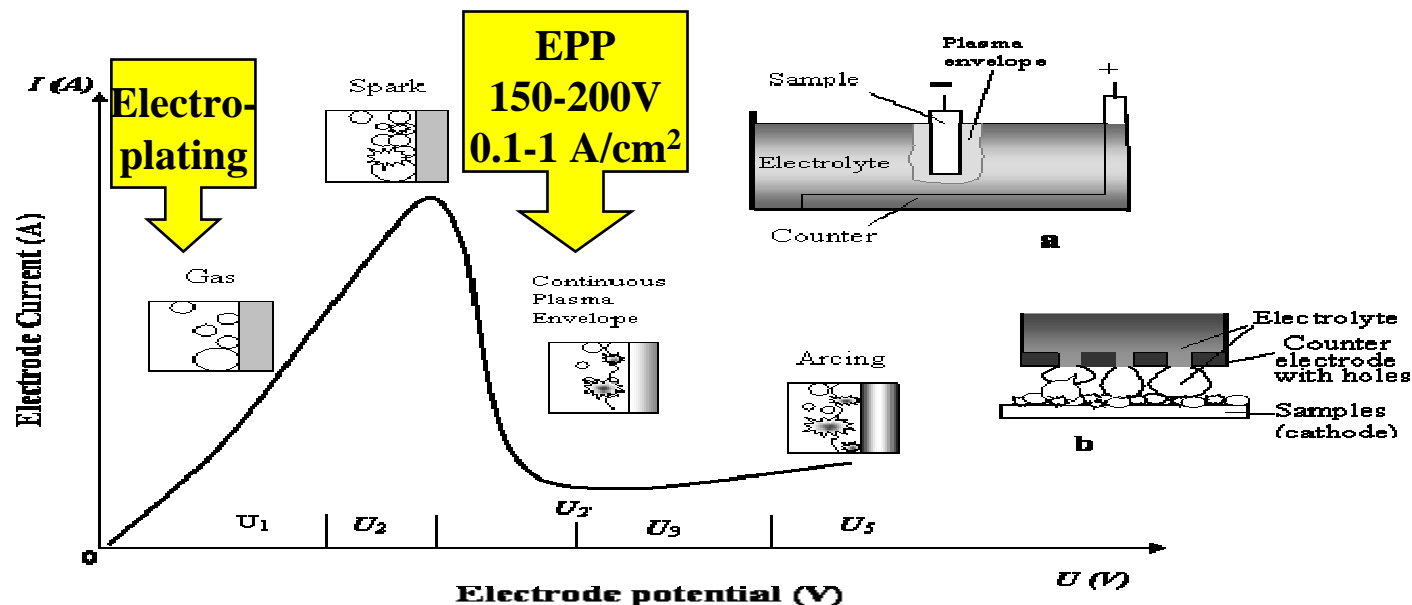
# Technical Objective

**Develop electrolytic plasma processing technology as an environmentally benign process for:**

- **Surface cleaning of high-strength steels in preparation for coating application**
- **Application of coatings exhibiting properties equivalent or superior to cadmium plating on high-strength steels**
  - **Capable of uniform deposition on internal surfaces and complex geometries**
  - **Does not degrade performance characteristics (e.g., fatigue) of base steel**

# Technical Background

- EPP is an aqueous process involving two phenomena
  - electrolysis of liquid by high potential (200V vs a few V for plating)
  - production of a plasma at or in the vicinity of the cathode (workpiece)
- Figure shows typical current-voltage characteristic curve
  - most electroplating operates in U<sub>1</sub> gas generation region
  - EPP operates around U<sub>2</sub> where continuous plasma envelope forms on surface
- Near-surface heating due to plasma enhances cleaning but bulk temperature remains relatively low



## Cleaning Studies:

- Can HSS be cleaned effectively without substrate damage?
  - extent of cleaning
  - hydrogen embrittlement
  - surface characteristics, microstructure
  - hardness and residual stress

## Coating Studies:

- Is Zn-Al & Zn-(Al-O/OH) coating quality adequate?
  - hydrogen embrittlement
  - composition, thickness uniformity
  - microstructure
  - characteristics (porosity, hardness)

**Selection of cleaned and coated material**  
**Conduct fatigue, corrosion, torque/tension measurements**

**Demonstrate cleaning and deposition of optimum coatings onto actual components provided by the military repair depots**

**Conceptual design of EPP system for demonstration at one or more military repair depots**

# Technical Approach – Year 1 Cleaning

**Study the characteristics of EPP-cleaned surfaces by varying process parameters to understand and optimize their effect**

**Motivation is not only the degree of surface cleanliness obtained but also the surface morphology and impact on properties of HSS**

## Property/Characteristic

Oxide thickness, organic contamination

Surface morphology (roughness)

Heat-affected zone thickness/ $\mu$ structure

H content near surface

H embrittlement

Residual stresses near surface

## Methodology

SEM/EDAX, AES, XPS

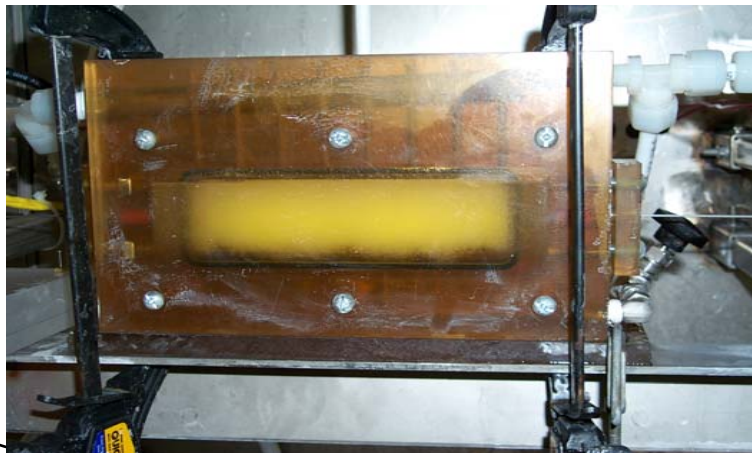
Optical profilometry, SEM

Xsection TEM and microhardness

Nuclear reaction analysis

ASTM F519 test

low-angle XRD



**Reactor at CAP Technologies for studying cleaning and coating deposition**

# Technical Approach – Year 1

## Coating

**Study the deposition of Zn-Al alloy and Zn-(Al-O/OH) composite coatings by varying process parameters to determine effects on composition and required performance characteristics**

**Motivation is to determine ability of EPP to deposit different coating compositions such that performance characteristics can be modified depending on in-service applications**

### Property/Characteristic

**Thickness uniformity, morphology**

**Composition, porosity**

**Microstructure**

**Residual stress**

**Adhesion**

**Microhardness**

### Methodology

**SEM, optical profilometry**

**SEM/EDAX (plan-view or Xsection)**

**TEM**

**XRD**

**ASTM D4541**

**Vickers or Knoop indenter**



**Measure performance characteristics of coatings developed in first year in comparison to cadmium plating and determine effects on base HSS material**

## **Property/Characteristic**

**Hydrogen embrittlement**

**Electrochemical evaluation**

**Salt-fog corrosion behavior**

**Fatigue**

**Wear**

**Torque/tension test (fasteners)**

## **Methodology**

**ASTM F-519 test**

**Anodic polarization**

**ASTM B117 test**

**ASTM E466 axial test**

**Pin-on-disk test**

**ARL-developed test**

**If previous studies prove efficacy of process related to coating performance and impact on base material, then:**

- **Demonstrate process for cleaning and coating of external and internal surfaces, and complex geometries**
- **Demonstrate process on selected components obtained from Naval Aviation Depot North Island, Ogden Air Logistics Center, and Anniston Army Depot**
- **Generate conceptual design of prototype EPP cleaning/coating system that could be utilized as a demonstration unit at a repair depot**